Mechanical analysis and research on railway stripping device

Xueling Li[1, a], Xiaoqiang Guo[1], Genwen Li[2], Hongfeng Ma[1]

[1]Jiangsu XCMG Construction Machinery Research Institute Ltd, Xuzhou, 221004, China

[2]XCMG. Xuzhou Truck-Mounted Crane Co., Ltd, Xuzhou, 221004, China

[a] Corresponding author: lixueling861126@163.com

Abstract. China's railway is developing rapidly, but most of the supporting maintenance equipment is imported, and the productivity of domestic equipment is weak. The wire stripping device is a professional equipment to set up, test and maintain the contact net, which can ensure the efficiency and safety of railway maintenance. In this paper, the wire stripping device is studied. Methods of theoretical calculation, mechanism kinematics, and finite element analysis are used. The mechanical properties of each part of the mechanism are analyzed. The results can provide theoretical guidance for practical production.

1.Introduction

China railway is developing rapidly in recent years, and the development of railway catenary scale expands unceasingly. Maintenance time shrank due to the increase of vehicle speed, capacity and density. The traditional maintenance depending on workers cannot meet the needs of the railway catenary maintenance [1]. The wire stripping device designed in this paper is installed on the integrated working vehicle of the contact network, which is used for set up, testing and maintenance of the railway contact network.

At present, domestic high-speed railway is developing unceasingly, but the supporting maintenance and maintenance equipment is mostly imported. In recent years, the research on railway maintenance equipment is also developing continuously. Zhang caixia et al. [2] used the levelling device of the operation platform to adapt to the situation of ultra-high external rail, so that the contact network operation platform was in a horizontal state and the operation safety was guaranteed; Yuan lei et al. [3] studied the structure of a multi-functional comprehensive working vehicle, redesigned its unreasonable design pattern and made its structural strength meet the requirements. Zhao jian et al. [4] modified the existing hydraulic system of the working vehicle to form an automatic levelling system, thus improving the reliability and safety stability of the fast multi-functional working vehicle. Cao yaling [5] designed the TY5 bogie through kinetic correlation calculation analysis and parametric optimization study, which made it have good dynamic characteristics. Aiming at the work requirements of railway contact net set-up and maintenance, in this paper the key techniques such as theoretical analysis, mechanism kinematics and finite element analysis are used, the components of the wire stripping device installed on the contact net work vehicle are studied, which providing theoretical guidance for practical production.

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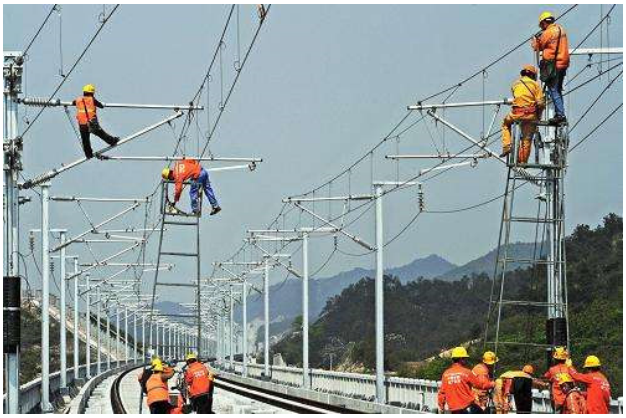


Fig. 1 Schematic diagram of traditional catenary work

2.Summary

The traditional wire height adjustment of tension contact network, or the detection and maintenance work often adopts the manual maintenance as shown in figure 1. The operation is dangerous and the maintenance cycle is long, which cannot meet the actual work requirements. Wire stripping device is a professional contact net set-up, testing and maintenance equipment, including base, sliding arm, expansion arm and stripping roller components, as shown in figure 2. The sliding arms of the device can achieve left and right horizontal movement of 675mm, which expand the operation range. The telescopic boom requires that the amplitude of variation should be 0º to 120º. The maximum working height of 5000mm can be achieved through telescopic boom operation. The wire pull roller can realize wire set-up and adjustment with the maximum horizontal pull force of 3000N and the maximum lift force of 3500N, as shown in figure 3.

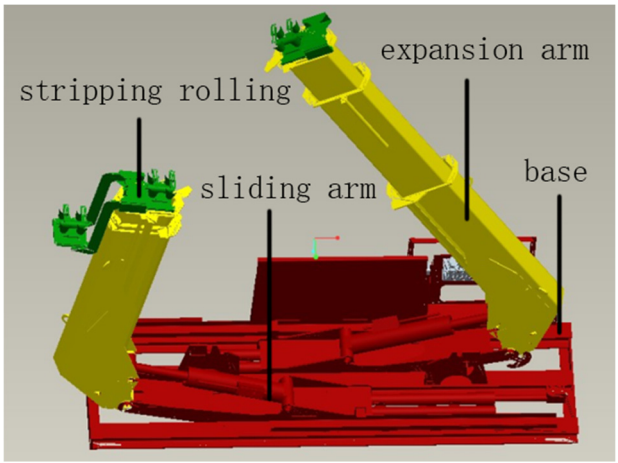


Fig. 2 Structure diagram of wire stripping device

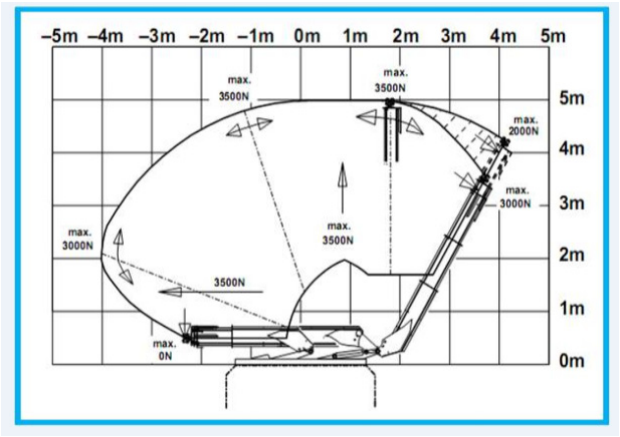


Fig. 3 Schematic diagram of operation scope

3.Structure calculation and analysis of wire stripping device

In luffing operation range, boom of wire stripping device bears its own gravity, stripping load and generate additional bending moment. Considering of the axial force of the telescopic boom generated by oil cylinder, the arm bears the maximum stress in luffing angle for 0º. Assuming that the stripping load is 3000N under the maximum stress working condition (actually the maximum stress working condition barely happens), which is used to design calculation of the arm force.

3.1 Strength calculation and analysis of expansion boom

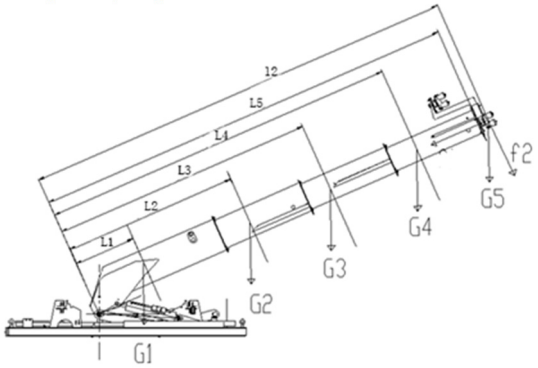


Fig. 4 The basic arm of telescopic boom

The normal stress generated the bending moment is $\sigma = M_{max}/W$, where M_{max} is the maximum bending moment and W is the bending modulus of this section. The basic arm of the telescopic boom structure is shown in figue 4. M_{base} is calculated when the luffing angle is 0:

$$\mathrm{M_{base}} = f_2 \times l_2 + \mathrm{G_1} \times \mathrm{L_1} + \mathrm{G_2} \times \mathrm{L_2} + \mathrm{G_3} \times \mathrm{L_3} + \mathrm{G_4} \times \mathrm{L_4} + \mathrm{G_5} \times \mathrm{L_5}$$

Strength check is performed on the luffing arm of the telescopic boom structure 1. The first luffing arm is shown in figure 5. M_1 is calculated when the luffing angle is 0:

$$\mathrm{M_1} = f_2 \times l_{2_1} + \mathrm{G_5} \times \mathrm{L_{5_1}} + \mathrm{G_4} \times \mathrm{L_{4_1}} + \mathrm{G_3} \times \mathrm{L_{3_1}} + \mathrm{G_2} \times \mathrm{L_{2_1}}$$

Similarly, the bending stress of the other arms was calculated, as shown in table 1. The arm body is made of Q690 material, and its yield strength $\sigma_s = 690$ MPa，elastic modulus $\mathrm{E} = 2.1 \times 10^5 \mathrm{N/mm^2}$，safety factor$\mathrm{N} = 2$, allowable stress $[\sigma] = 345\mathrm{MPa}$. The strength condition that the arm body section should meet is$\sigma_f < [\sigma]$, where σ_f is the bending stress. The stress results are much lower than the allowable stress, so the structure strength meets the strength design requirements.

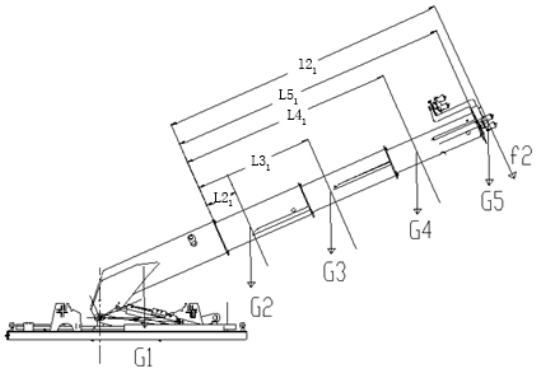


Fig. 5 The 1st arm of telescopic boom

Tab. 1 The bending stress result of each arm of telescopic boom

	basic	1st	2nd	3rd
σ_f/MPa	57.4	58.7	45	28

3.2 Calculation and analysis of expansion arm stiffness

Luffing deflection of telescopic boom is calculated, which consulted the crane conveyor metal structure [6]. For the telescopic arm of wire stripping device, end deflection of arm is $f_w = \sum_1^k f_i + \sum_{i=1}^{k-1} \theta_{i+1} H_{i+1}$, where the number k for arm section; f_i for the endpoint line displacement of arm i, θ_{i+1} for the rotation angle of arm i circled arm i+1; H_{i+1} for the distance between two end of arm i. The deflection f_{i+1} and the rotation angle $\theta_{i+1}$are calculated according to arm i.

According to 3811-2008 "the crane design standard" [7] chapter 5.5.2.3.1, box type telescopic boom stiffness requirement, lifting rated load and only considering the deformation of boom, the relationship between displacement f_L of boom end and boom length L_c is $f_L \leq 0.1 \times (\frac{L_c}{100})^2$, The allowed maximum deflection is calculated, which is 28.5mm.

The deflection of arm end of the stripping device is $f_w = 7.32\text{mm} < 28.5\text{mm}$, which meets the stiffness design requirements.

4.Dynamic analysis of wire stripping device

The luffing action of the wire stripping device is realized by the hydraulic cylinder. Its working load is the stripping load, and the maximum transverse force is 3000N and axial force is 3500N. The dynamic calculation model of the wire stripping device is established, as shown in figure 6.

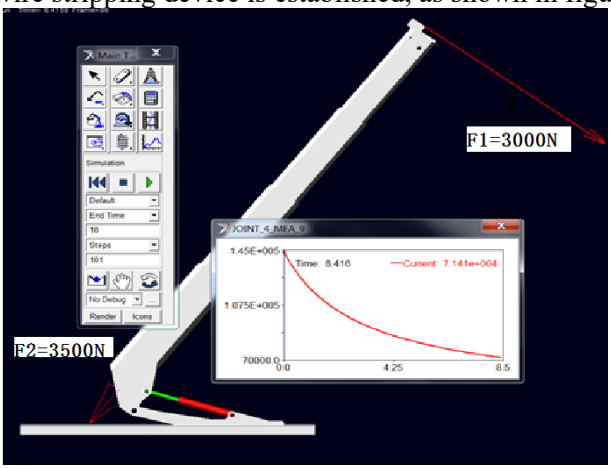


Fig. 6 The dynamic analysis model of wire stripping device

In the luffing range, the maximum load of key hinge points is obtained as shown in figure 7. The maximum load at the hinge point 1 between telescopic boom and base is 9.75×10^4N; The maximum load of hinge points 2 and 3 at both ends of luffing hydraulic cylinder is 8.34×10^4N. According to the maximum load of hinge points, the bearing capacity of each pin shaft of the alignment device is acquired and satisfied to the requirements.

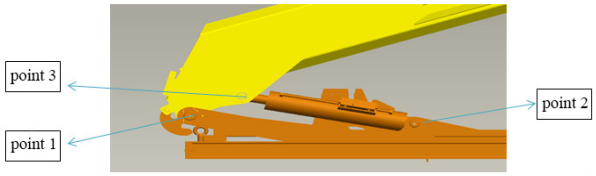


Fig. 7 The schematic diagram of hinge position

The luffing range of the stripping device requires from 0º to 120 º and the load of hydraulic cylinder is calculated and checked as shown in figure 8. The maximum load of the hydraulic cylinder in the luffing range is obtained as follows: $F_{push_max} = 8.68 \times 10^4$ N and $F_{pull_max} = 4.56 \times 10^4$ N, respectively. Compared to the hydraulic cylinder design manual, the type of hydraulic cylinder meets the design requirements.

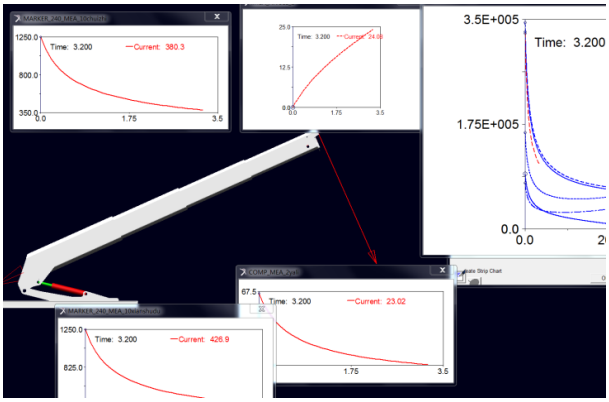
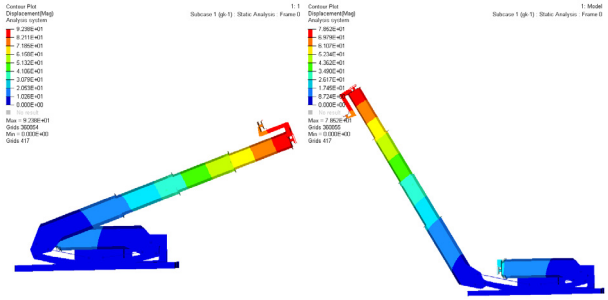


Fig. 8 The calculation model of variable amplitude cylinder

5.Finite element analysis of wire stripping device

The FEA model of wire stripping device was established and calculated by the commercial software Hyperworks. The material properties, contact types and boundary conditions are set up as follows: the base of the wire stripping device is fixed to the vehicle by multiple bolts, which is simplified to the bottom full constraint. In working condition, according to the rated load the maximum stripping force, 3000N, and the maximum lifting force, 3500N, is set. In the meanwhile, according to the design manual of GB/T 3811-2008 design rules for cranes, the wind pressure is set to 95.6N/m^2. And all loads are applied with a safety factor of 1.5.



20º amplitude range 120º amplitude range

Fig. 9 The stress of wire stripping device

Based on the Optistruct results, the maximum side displacement of wire stripping device is acquired on the side of the sliding arm while the luffing arm is fully extended. The most dangerous working condition is happened when the luffing angle is 20ºand 120º, respectively.

The hydraulic cylinder load is 74300N and 43700N, which is consistent with the calculated results, when the luffing angle is 20º and 120º, respectively. The deformation results of the wire stripping device are shown in Fig. 9 under the two most dangerous working conditions of luffing angle 20º and 120º, respectively. The maximum deformation is 92mm and 78mm, respectively. The deformation is small compared to the deformation of the whole vehicle, which meets the rigidity safety requirements. It can be seen from Fig. 10 that the area of the whole vehicle stress over 90% is within 100 MPa under the most dangerous working condition, which completely meets the use requirements of steel Q690. Large areas of stress all occurred near the contact part and hinge points of the telescopic boom. Due to stress concentration at the contact part, the maximum value is around 270MPa and 230MPa respectively. The safety coefficient of the whole vehicle can reach at least 2.5, which definitely meets the strength safety requirements.

6.Conclusions

In this paper the structure of the wire stripping device is analyzed, and the theoretical calculation, dynamic analysis and finite element analysis are applied to study the mechanical performance of all parts of wire stripping device, which can provide theoretical guidance for practical production.

(1) Mechanical calculation was conducted for the telescopic arm structure of the wire stripping device, and the bending strength and deflection of each arm were analyzed and calculated. And the results meet the design requirements.

(2) The mechanical dynamic design technology was used, the key hinge points of the transmission mechanism and bearing strength of the wire stripping device were calculated and checked; The luffing hydraulic cylinder is calculated and checked.

(3) The rigid strength of the wire stripping device was checked by finite element analysis technology, and the results show that it fully meets the design requirements. The design is safe and reliable.

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